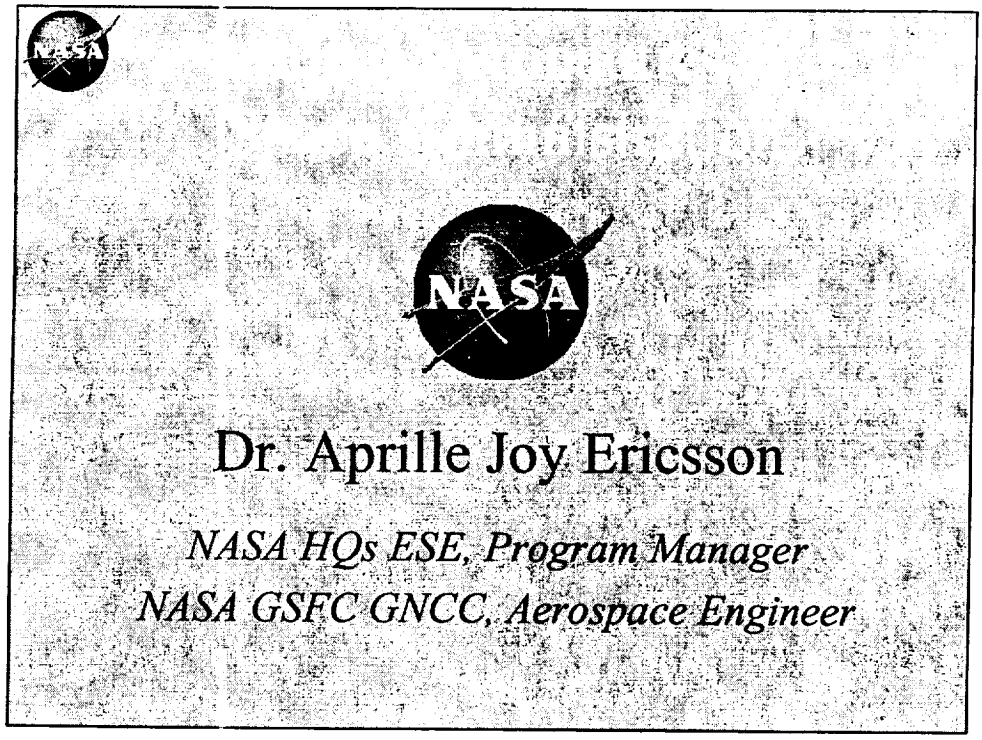
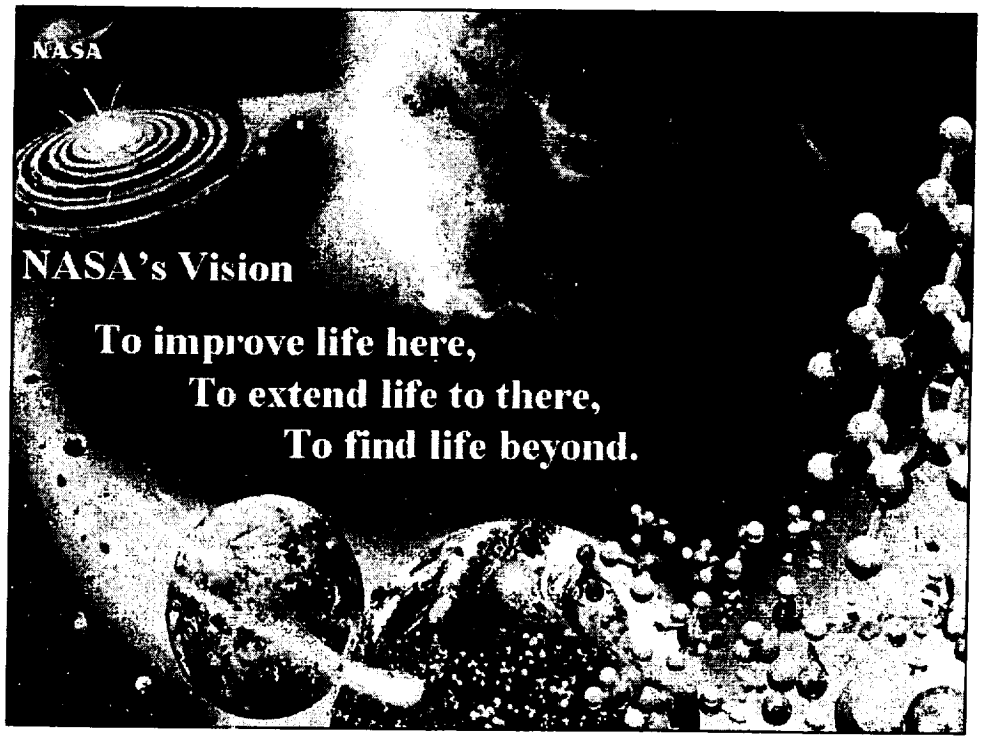

NASA
NASA
Dr. Aprille Joy Ericsson
NASA HQs ESE, Program Manager
NASA GSFC GNCC, Aerospace Engineer


NASA
NASA's Vision
To improve life here,
To extend life to there,
To find life beyond.

NASA

NASA Mission

To understand and protect our home planet

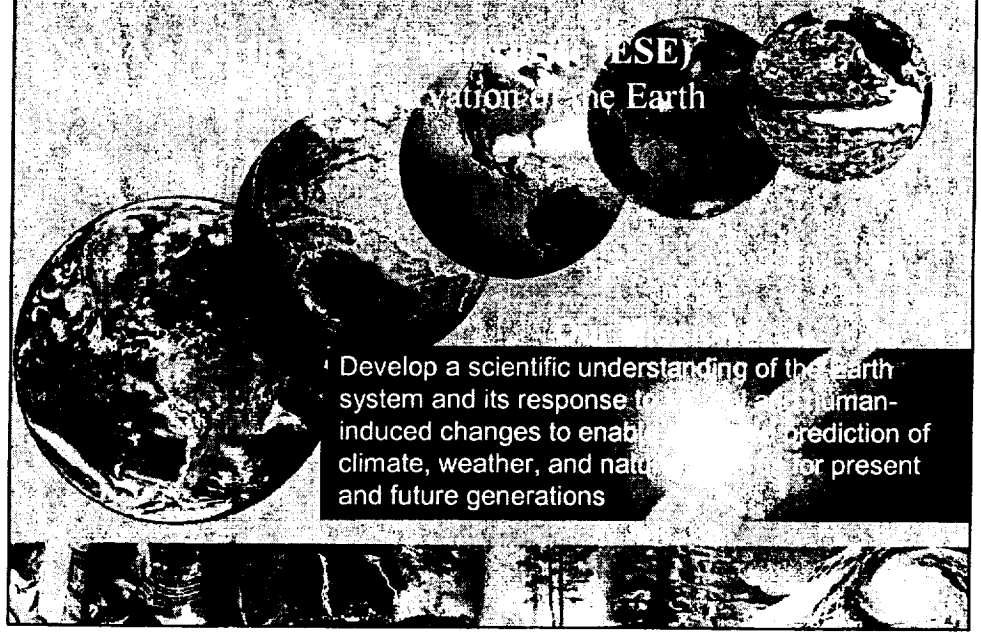
To explore the universe and search for life

To inspire the next generation of explorers

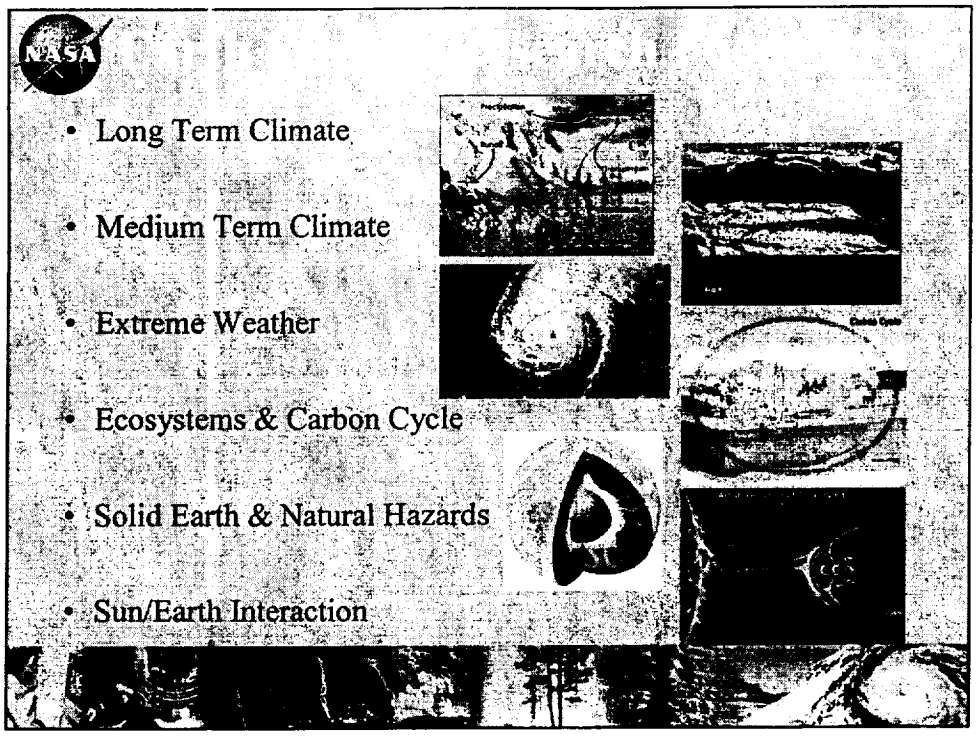
...as only NASA can.

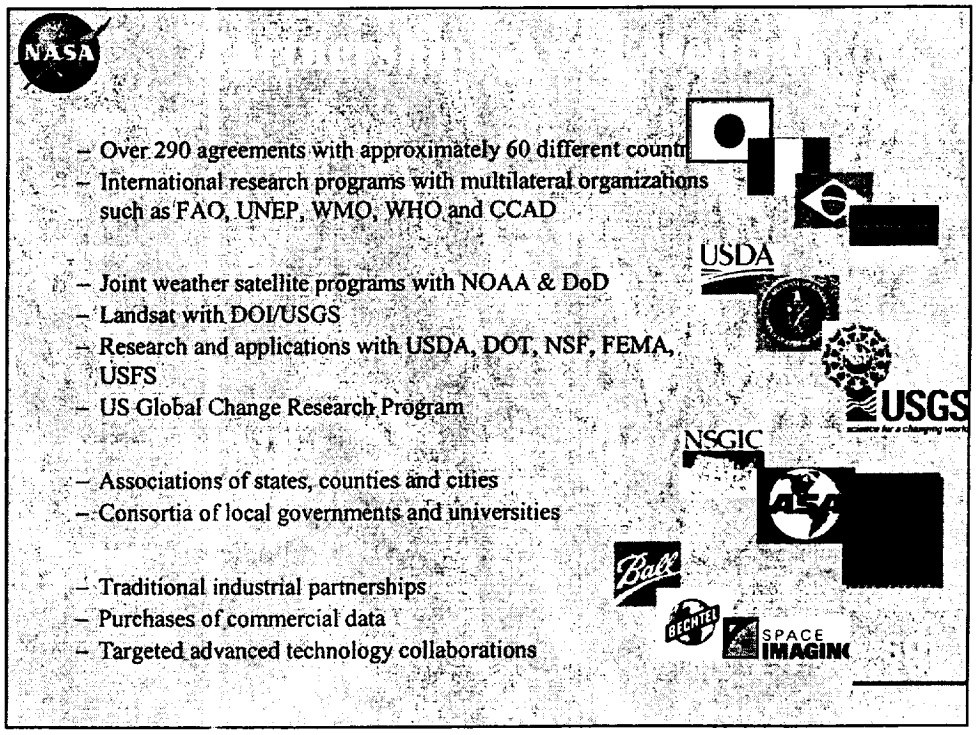
NASA

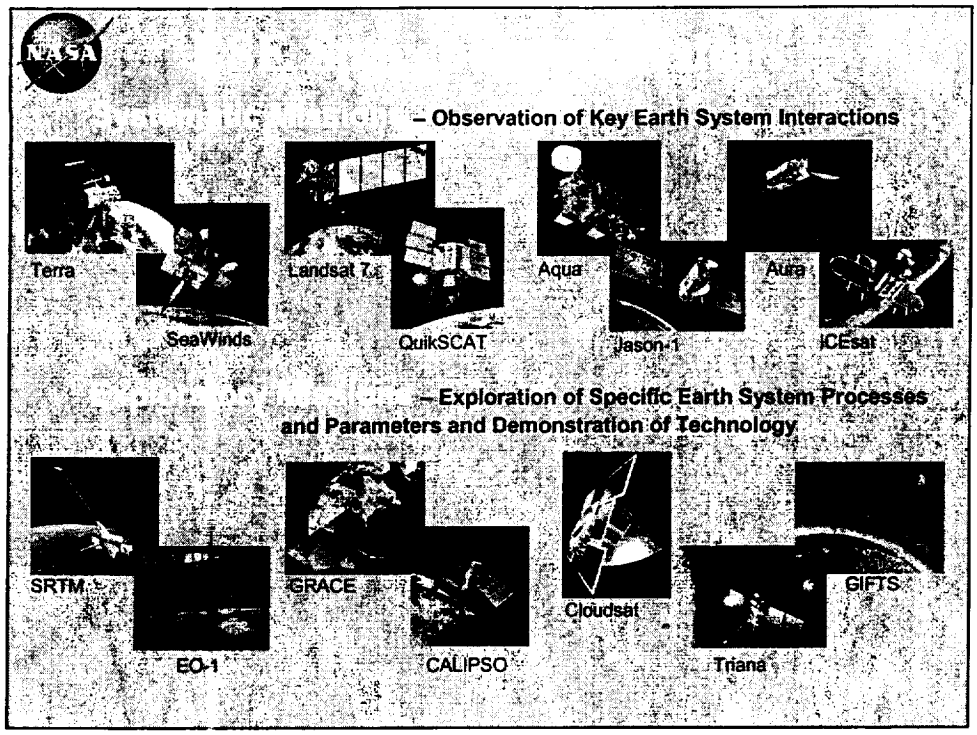
Earth Vision Introduction

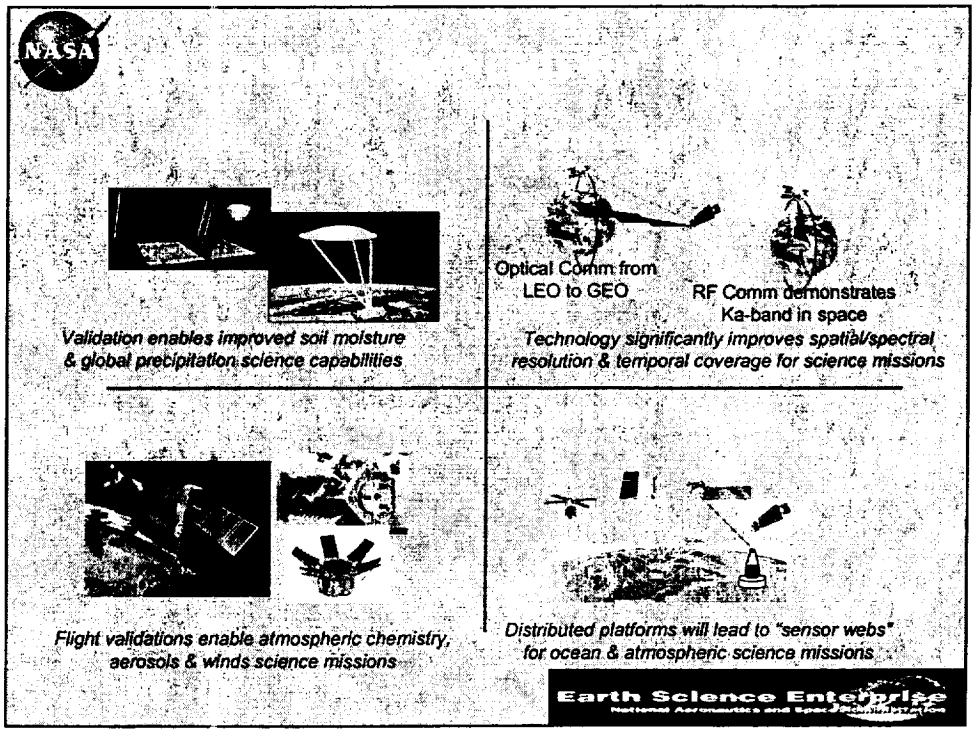


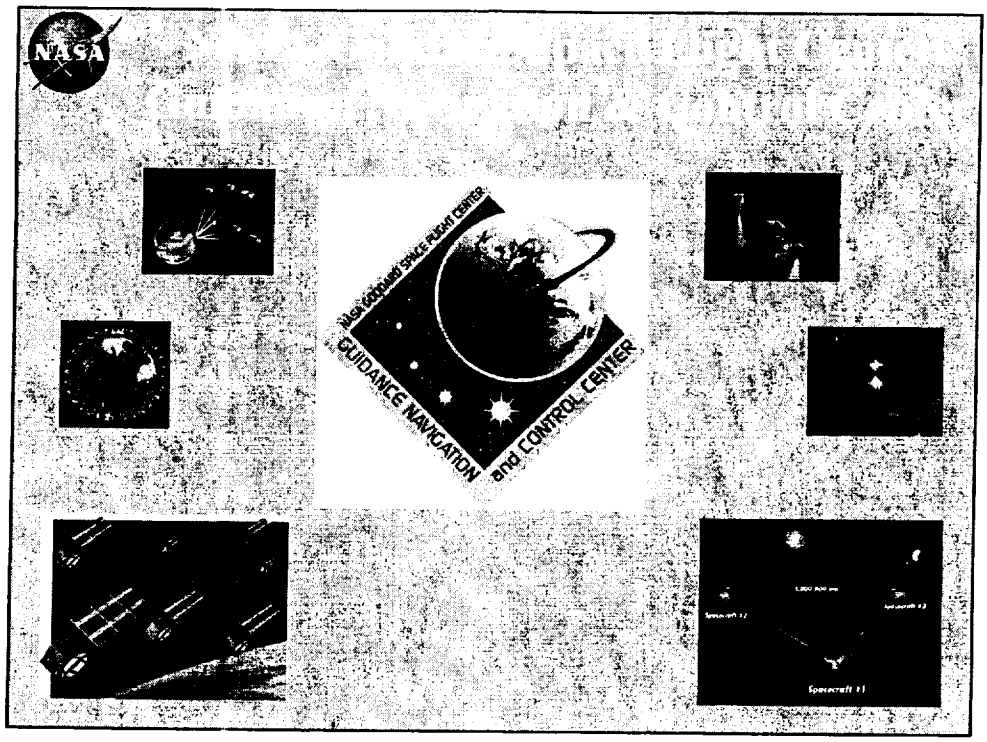
- Develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable prediction of climate, weather, and natural hazards for present and future generations


• Long Term Climate
• Medium Term Climate
• Extreme Weather
• Ecosystems & Carbon Cycle
• Solid Earth & Natural Hazards
• Sun/Earth Interaction


– Over 290 agreements with approximately 60 different countr
– International research programs with multilateral organizations such as FAO, UNEP, WMO, WHO and CCAD
– Joint weather satellite programs with NOAA & DoD
– Landsat with DOI/USGS
– Research and applications with USDA, DOT, NSF, FEMA, USFS
– US Global Change Research Program
– Associations of states, counties and cities
– Consortia of local governments and universities
– Traditional industrial partnerships
– Purchases of commercial data
– Targeted advanced technology collaborations
USDA
USGS
NSGIC
Ball
BECHTEL
SPACE IMAGING


– Observation of Key Earth System Interactions
Terra
SeaWinds
Landsat 7
QuikSCAT
Aqua
Jason-1
Aura
ICEsat
– Exploration of Specific Earth System Processes
and Parameters and Demonstration of Technology
SRTM
EO-1
GRACE
CALIPSO
Cloudsat
Triana
GIFTS


Validation enables improved soil moisture
& global precipitation science capabilities
Optical Comm from
LEO to GEO
RF Comm demonstrates
Ka-band in space
Technology significantly improves spatial/spectral
resolution & temporal coverage for science missions
Flight validations enable atmospheric chemistry,
aerosols & winds science missions
Distributed platforms will lead to "sensor webs"
for ocean & atmospheric science missions
Earth Science Enterprise



NASA **Guidance, Navigation & Control Center (GN&C**

Vision

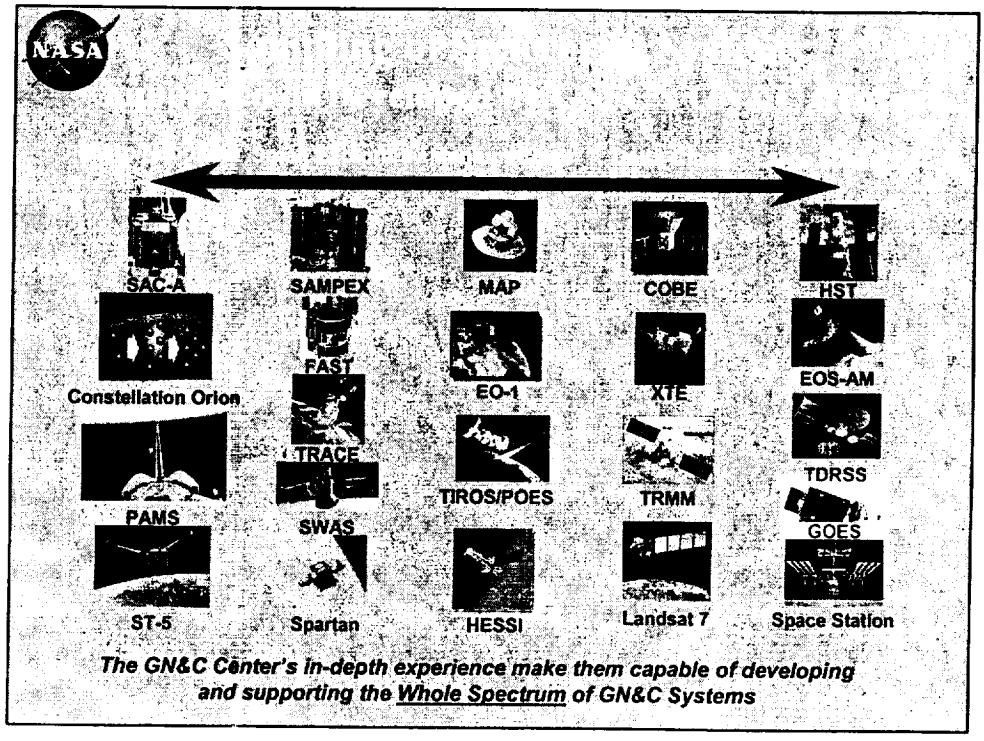
We are the premier GN&C organization providing innovative solutions that help Revolutionize Earth and Space Science Missions

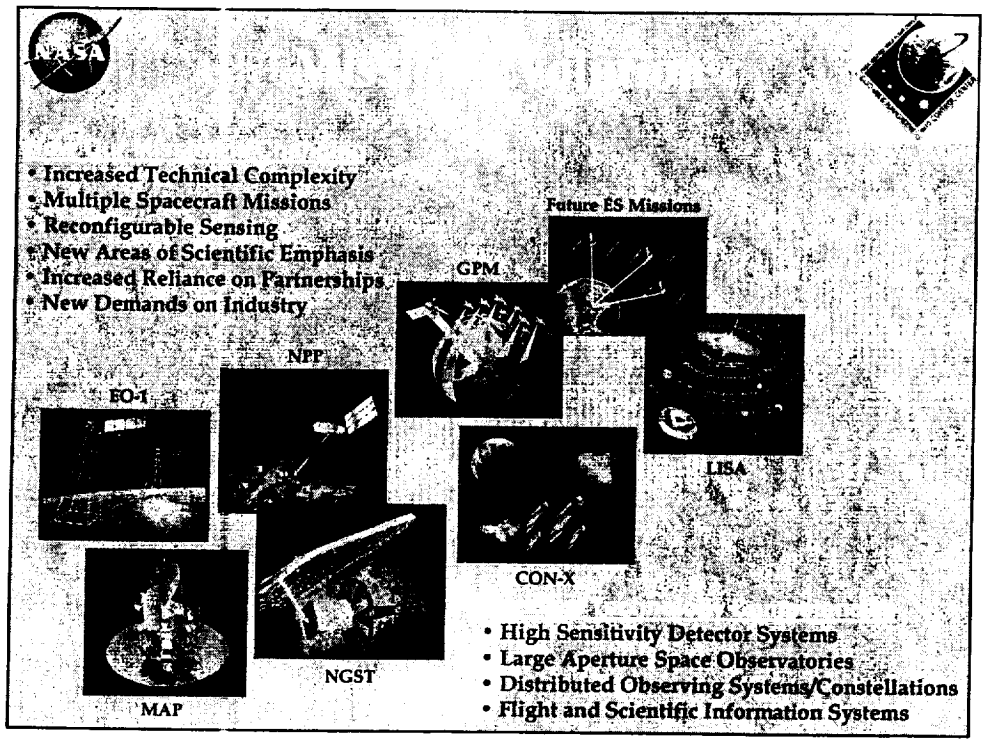
Mission

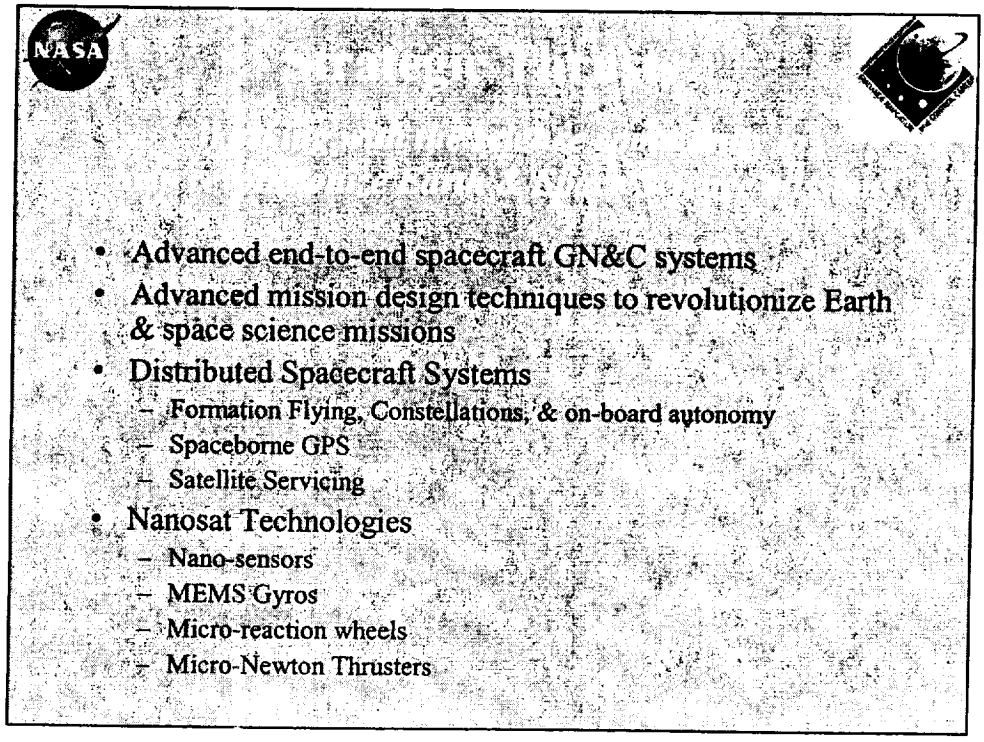
Enable earth and space science missions by:

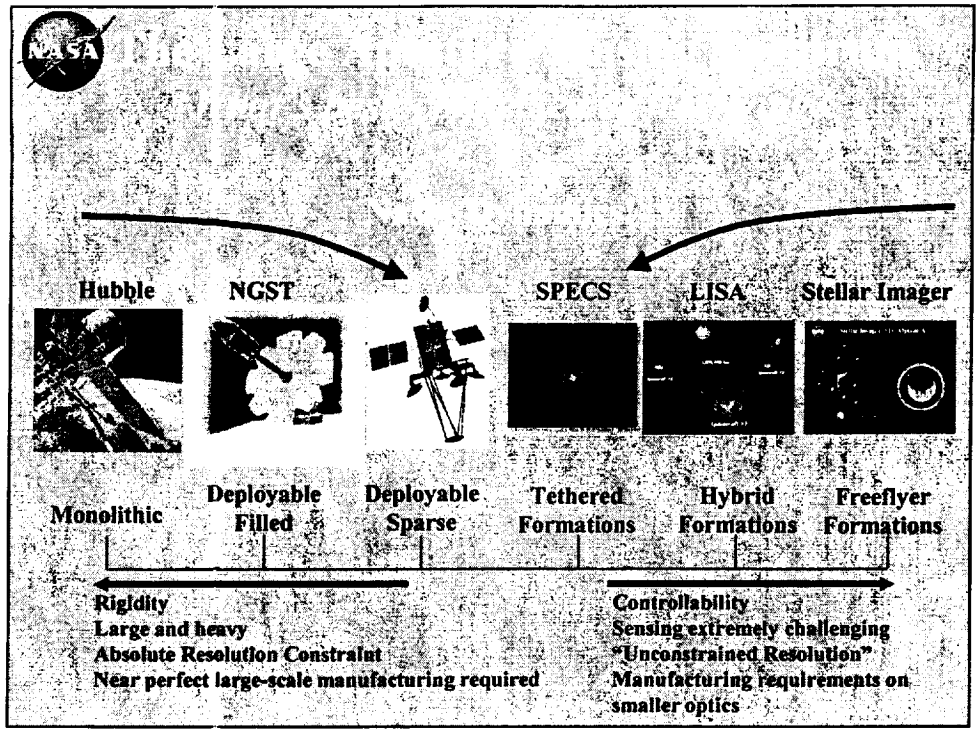
- *Providing GN&C applied engineering*
- *Leading GN&C technology development*

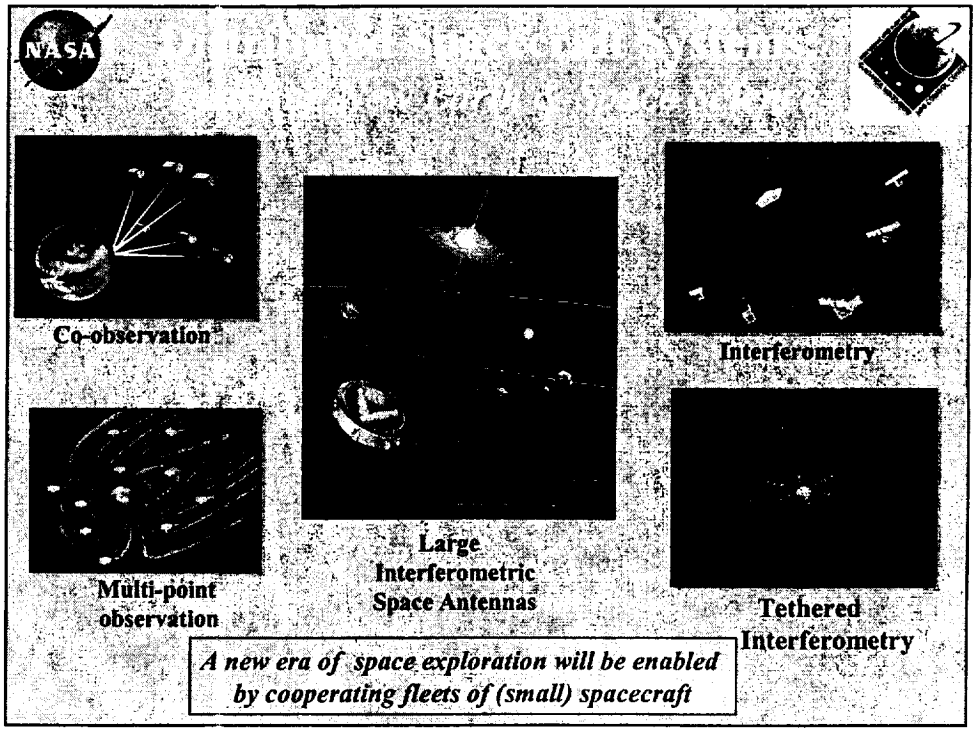

•Flight projects subsystem engineering
•Conceptual Design Leadership
•Satellite Re-entry/Orbit Debris
•ULDB Systems Engineering @ WFF
•WFF GN&C Systems
•Attitude & Trajectory Analysis
•Control System & Autonomous Systems Design
•Dynamics analysis
•Formation Flying & Constellation Analytic Techniques
•Mission Design
•Advanced Propulsion Systems Development
•ELV Propulsion Expertise
•Plume & Residual Gas Analyses
•Advanced Sensor & Actuator Development
•GN&C Hardware Systems
•Hybrid Dynamic Simulator Systems
•Component GSE
•Formation Flying Testbed & On-Orbit Testbeds


SAC-A
SAMPEX
MAP
COBE
HST
Constellation Orion
FAST
EO-1
XTE
EOS-AM
TRACE
TDRSS
PAMS
TIROS/POES
TRMM
SWAS
GOES
ST-5
Spartan
HESSI
Landsat 7
Space Station
The GN&C Center's in-depth experience make them capable of developing and supporting the Whole Spectrum of GN&C Systems


• Increased Technical Complexity
• Multiple Spacecraft Missions
• Reconfigurable Sensing
• New Areas of Scientific Emphasis
• Increased Reliance on Partnerships
• New Demands on Industry
Future ES Missions
GPM
NPP
EO-1
LISA
CON-X
NGST
MAP
• High Sensitivity Detector Systems
• Large Aperture Space Observatories
• Distributed Observing Systems/Constellations
• Flight and Scientific Information Systems


• Advanced end-to-end spacecraft GN&C systems
• Advanced mission design techniques to revolutionize Earth & space science missions
• Distributed Spacecraft Systems
– Formation Flying, Constellations, & on-board autonomy
– Spaceborne GPS
– Satellite Servicing
• Nanosat Technologies
– Nano-sensors
– MEMS Gyros
– Micro-reaction wheels
– Micro-Newton Thrusters


Hubble
NGST
SPECS
LISA
Stellar Imager
Monolithic
Deployable Filled
Deployable Sparse
Tethered Formations
Hybrid Formations
Freeflyer Formations
Rigidity
Large and heavy
Absolute Resolution Constraint
Near perfect large-scale manufacturing required
Controllability
Sensing extremely challenging
"Unconstrained Resolution"
Manufacturing requirements on smaller optics


Co-observation
Interferometry
Multi-point observation
Large Interferometric Space Antennas
Tethered Interferometry
A new era of space exploration will be enabled by cooperating fleets of (small) spacecraft

Landsat-7 / Earth Observer-1 Co-observing Program

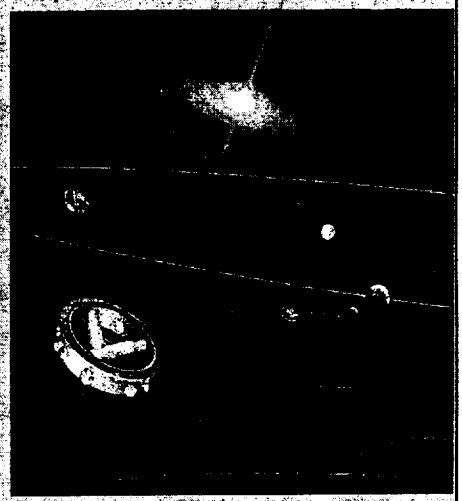
Cross-calibration of Earth Observer-1 instruments and demonstration of improvements in science

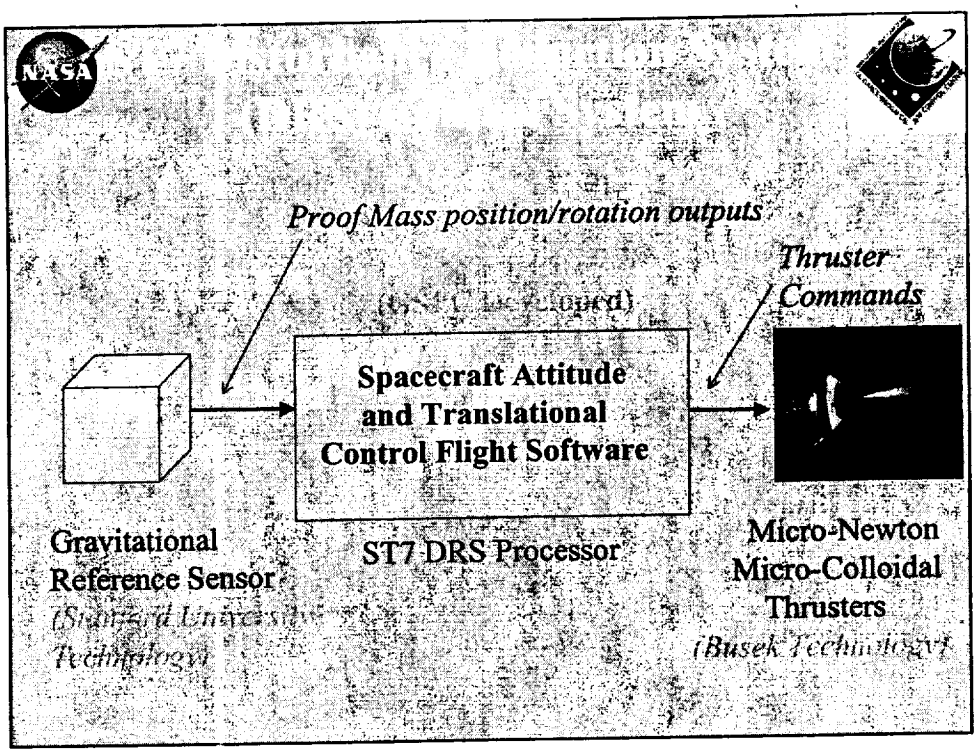
Landsat-7 launch, July 1999
Earth Observer-1 launch, November 2000
Two satellites fly in along-track formation

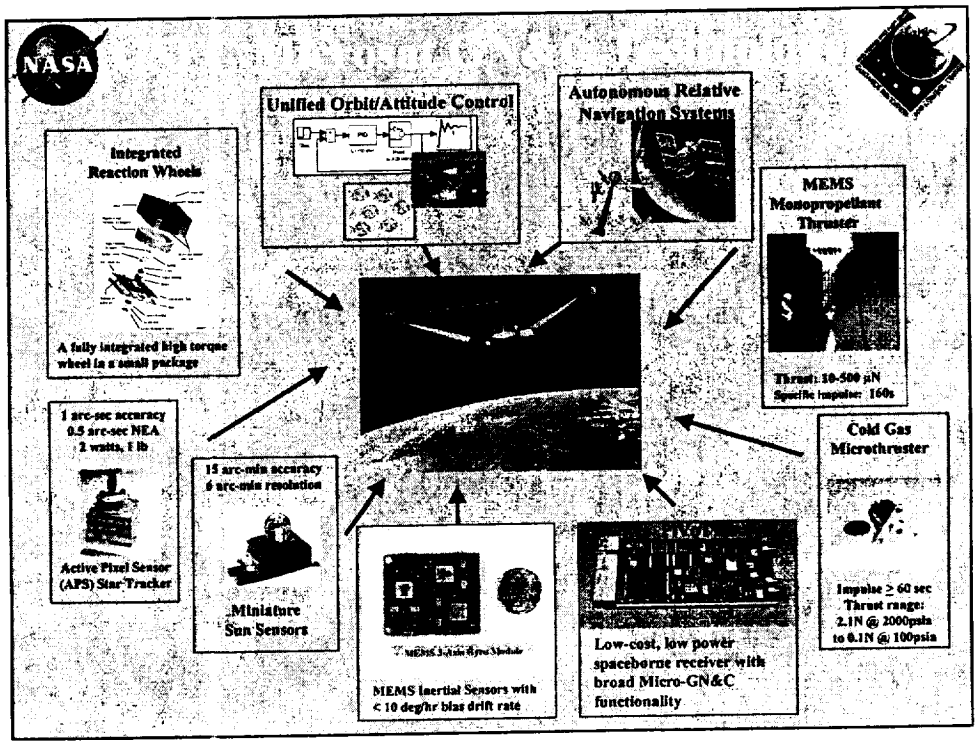
Earth Observer 1 flies over same ground track as Landsat-7

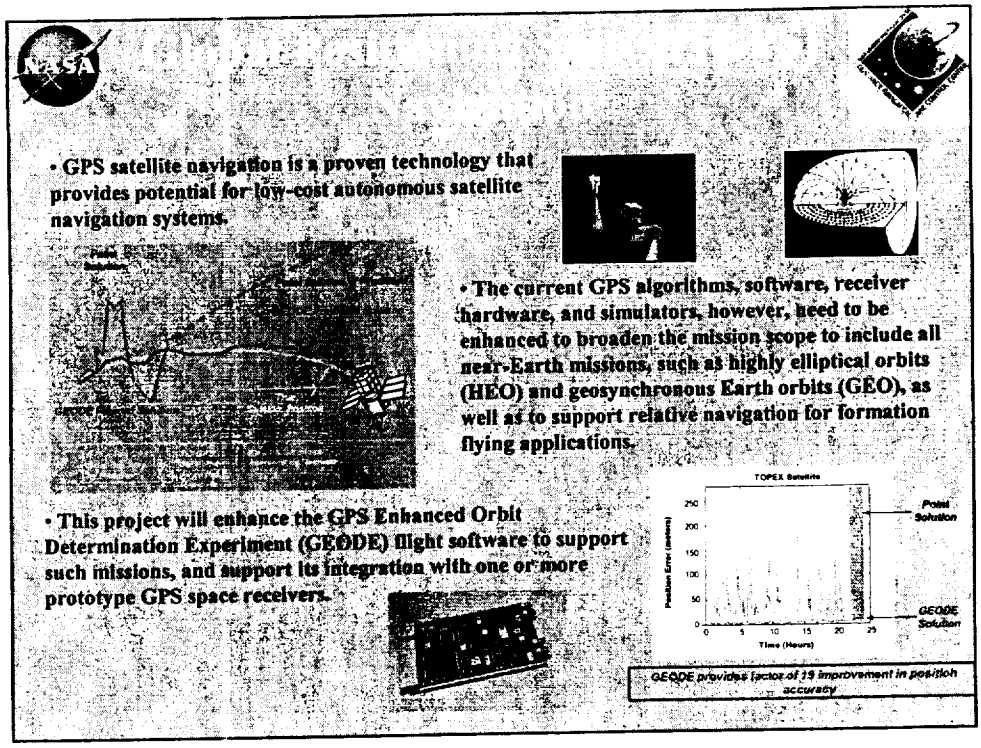
Nominal 1-minute +/- 6 second spacecraft separation (450km along-track separation)

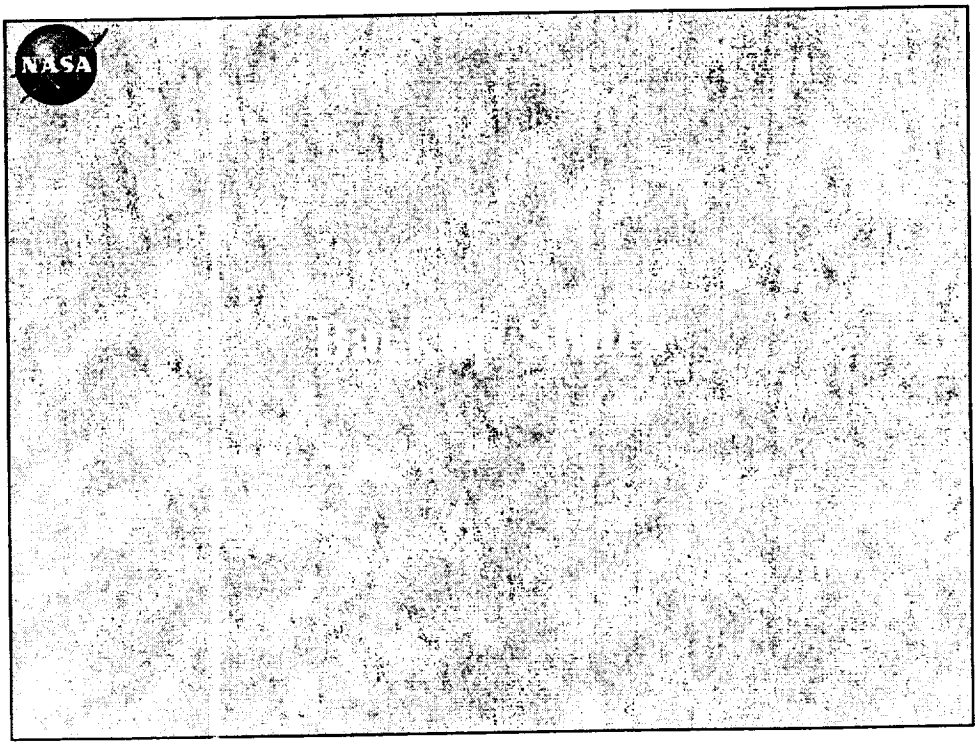
- 3 spacecraft separated by 5,000,000 km form a three-arm 'Michelson Interferometer' to observe gravitational waves in a 10^{-4} to 10^{-1} Hz bandwidth
- Each spacecraft payload includes two freely falling proof masses which serve as arm "end mirror" optical references
- Test masses must be free of non-gravitational forces (geodesically pure)
- Gravitational waves cause change in optical path in one arm of interferometer relative to other arm
- Distance changes measured with picometer precision to detect gravitational wave strains down to 10^{-23}
- Disturbance Reduction System (DRS) uses proof mass displacement sensor outputs to drive low-noise micro-Newton thrusters for 'drag-free' system operation

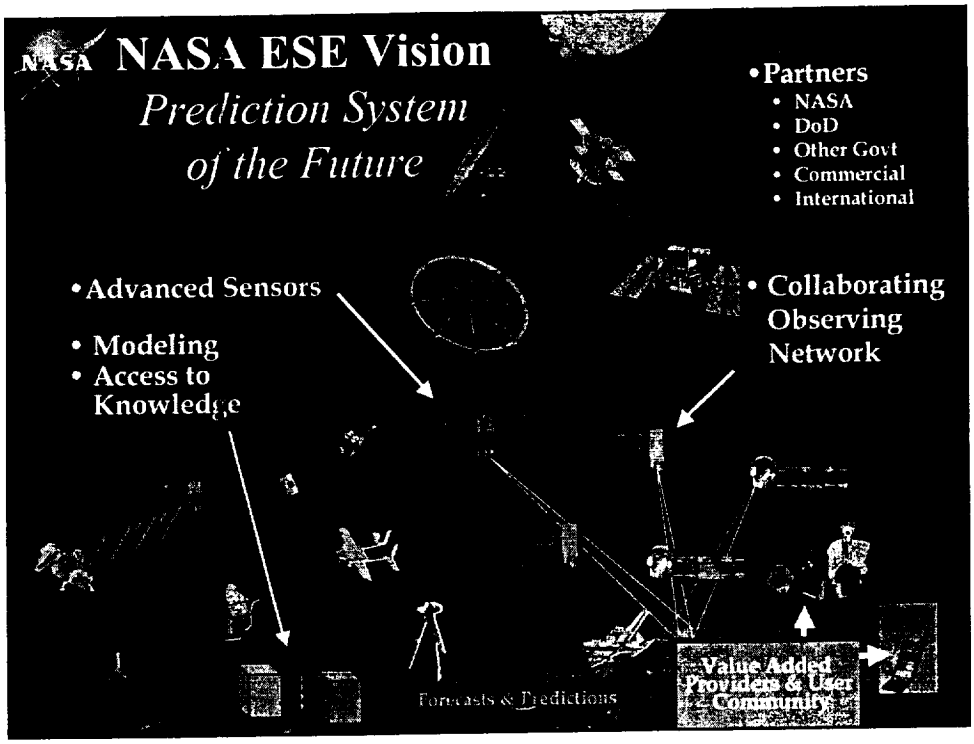


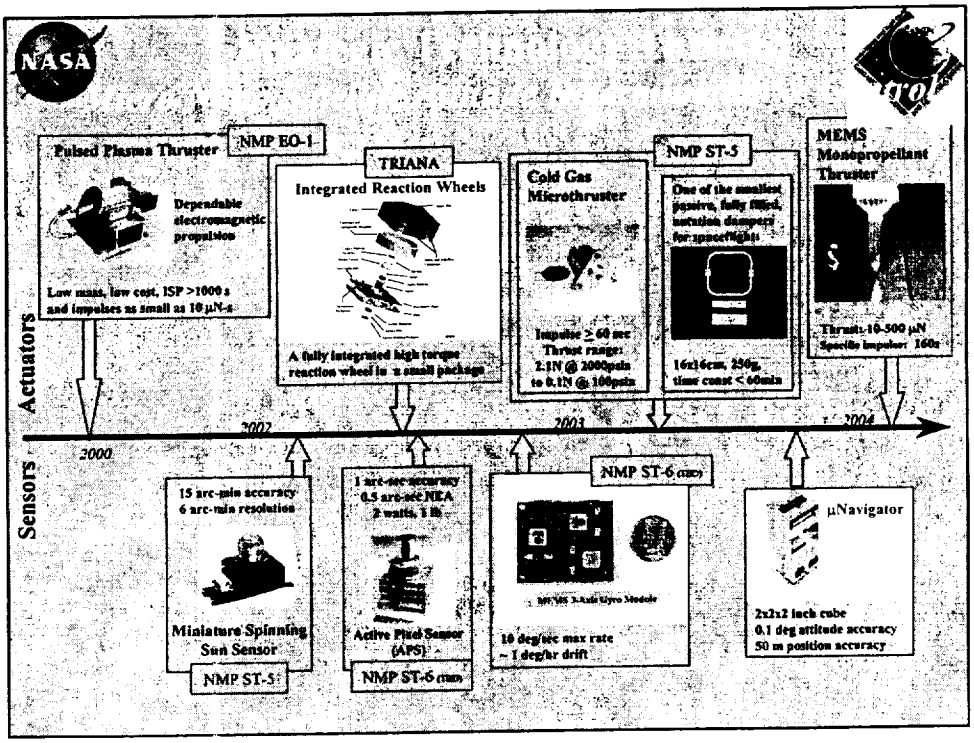

Proof Mass position/rotation outputs
Thruster Commands
Spacecraft Attitude and Translational Control Flight Software
Gravitational Reference Sensor
ST7 DRS Processor
Micro-Newton Micro-Colloidal Thrusters

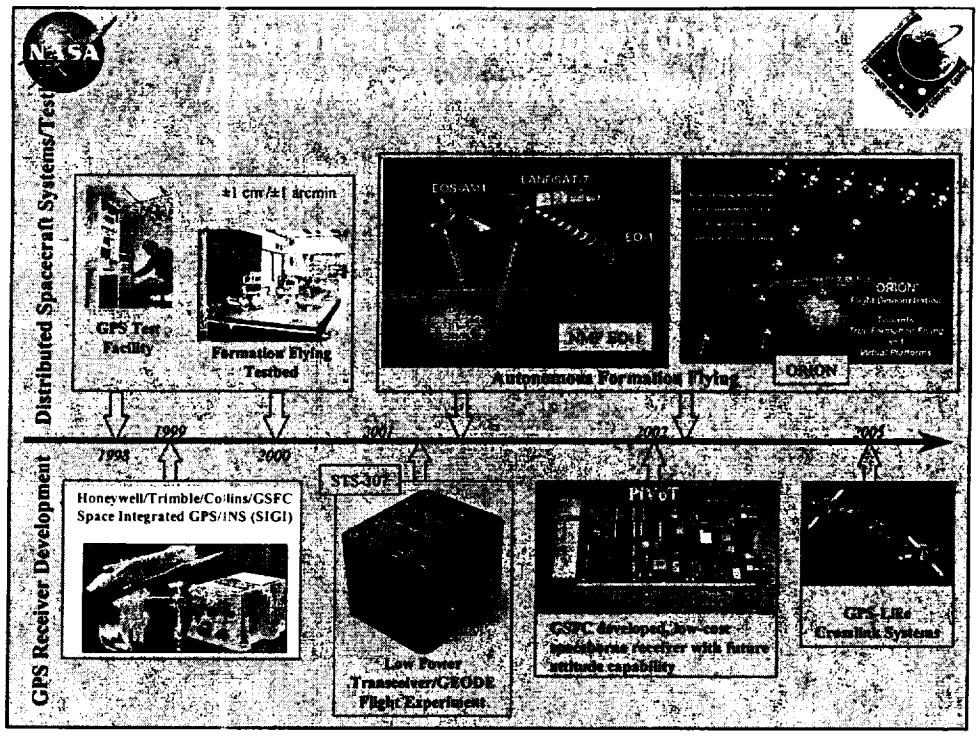

Integrated Reaction Wheels
A fully integrated high torque wheel in a small package
Unified Orbit/Attitude Control
Autonomous Relative Navigation Systems
MEMS Monopropellant Thruster
1 arc-sec accuracy
0.5 arc-sec NEA
2 watts, 1 lb
Active Pixel Sensor (APS) Star Tracker
15 arc-min accuracy
6 arc-min resolution
Miniature Sun Sensors
MEMS inertial Sensors with < 10 deg/hr bias drift rate
Low-cost, low power spaceborne receiver with broad Micro-GN&C functionality
Cold Gas Microthruster
Impulse ≥ 60 sec
Thrust range:
2.1N @ 2000psia
to 0.1N @ 100psia

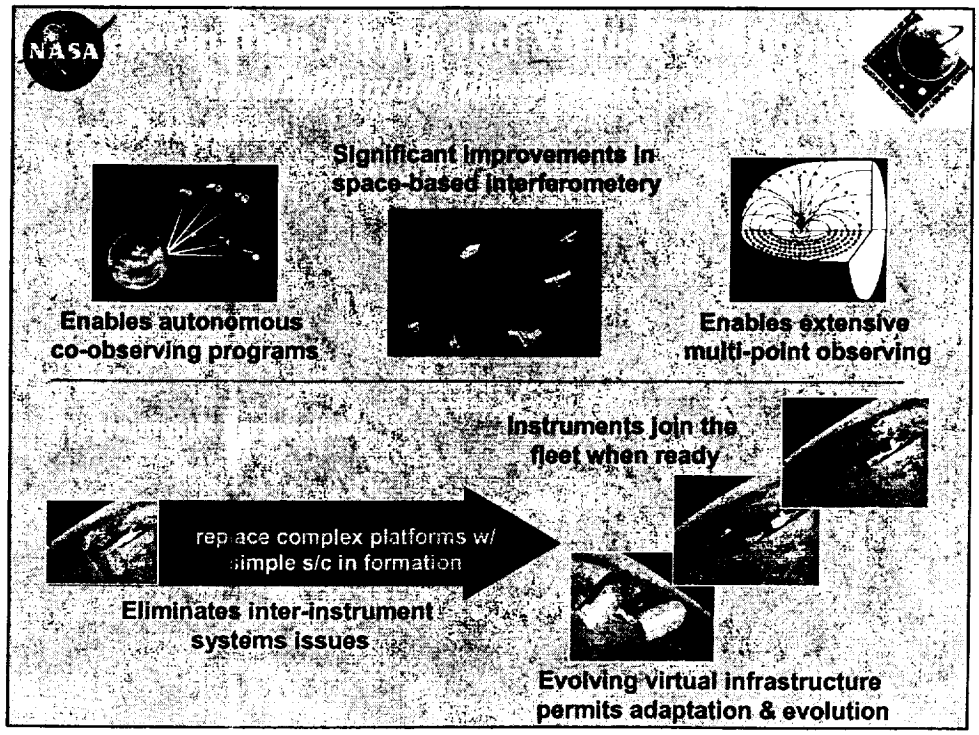

• GPS satellite navigation is a proven technology that provides potential for low-cost autonomous satellite navigation systems.
• The current GPS algorithms, software, receiver hardware, and simulators, however, need to be enhanced to broaden the mission scope to include all near-Earth missions, such as highly elliptical orbits (HEO) and geosynchronous Earth orbits (GEO), as well as to support relative navigation for formation flying applications.
• This project will enhance the GPS Enhanced Orbit Determination Experiment (GEODE) flight software to support such missions, and support its integration with one or more prototype GPS space receivers.
TOPEX Satellite
Position Error (meters)
Time (Hours)
Point Solution
GEODE Solution
GEODE provides factor of 19 improvement in position accuracy




NASA ESE Vision
Prediction System of the Future
•Partners
• NASA
• DoD
• Other Govt
• Commercial
• International
•Advanced Sensors
• Modeling
• Access to Knowledge
• Collaborating Observing Network
Forecasts & Predictions
Value Added Providers & User Community


NASA
Actuators
Sensors
Pulsed Plasma Thruster
NMP EO-1
Dependable electromagnetic propulsion
Low mass, low cost, ISP >1000 s and impulses as small as 10 μN-s
TRIANA
Integrated Reaction Wheels
A fully integrated high torque reaction wheel in a small package
Cold Gas Microthruster
Impulse ≥ 60 mc
Thrust range: 2.1N @ 2000psia to 0.1N @ 100psia
NMP ST-5
16x16cm, 250g, time const < 60mins
MEMS Monopropellant Thruster
Thrust: 10-500 μN
2000
2002
2003
2004
15 arc-min accuracy
6 arc-min resolution
Miniature Spinning Sun Sensor
NMP ST-5
1 arc-sec accuracy
0.5 arc-sec NEA
2 watts, 1 lb
Active Pixel Sensor (APS)
NMP ST-6 (APS)
NMP ST-6 (GIRO)
10 deg/sec max rate
~ 1 deg/hr drift
μNavigator
2x2x2 inch cube
0.1 deg attitude accuracy
50 m position accuracy


NASA
Distributed Spacecraft Systems/Test
GPS Receiver Development
GPS Test Facility
±1 cm/±1 arcmin
Formation Flying Testbed
EOS-AM1
LANDSAT 7
EO-1
NMP EO-1
Autonomous Formation Flying
ORION
ORION
1998
1999
2000
2001
2002
2003
Honeywell/Trimble/Collins/GSFC Space Integrated GPS/INS (SIGI)
STS-301
Low Power Transceiver/GEODE Flight Experiment
PiVoT
GSFC developed, low-cost spaceborne receiver with future attitude capability
GPS LRe
Crosslink Systems


NASA
Significant improvements in space-based interferometery
Enables autonomous co-observing programs
Enables extensive multi-point observing
Instruments join the fleet when ready
replace complex platforms w/ simple s/c in formation
Eliminates inter-instrument systems issues
Evolving virtual infrastructure permits adaptation & evolution